

Making Safety by Tying the Knot: Examining Resilience in Shipping

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Abstract. This paper reports on work to assess and promote resilience in the teams on ship bridges. Resilience and coping with complexity at a working level in the regulation of ship bridges is discussed. Shipping is presented as a system of systems, operating with different time constants. The properties of these interacting systems are discussed.

1 INTRODUCTION

The context of the paper is the rapid introduction of automation technology to the bridges of merchant ships. It examines what happens on the bridge (the sharp end), and examines the data flows, control loops and feedback loops between trainers, manufacturers, and regulators/standards setters (the blunt end).

In the maritime domain (as in many others) there is little data on how people actually provide resilience at the sharp end. This paper reports on an attempt to learn what people have to do to cope with clumsy automation and changes e.g. equipment failure. This attempt is the MTO-sea project, in which data is gathered, using multiple methods, by final year cadets from Kalmar Maritime Academy. Examinations of the sub-systems at the blunt end are relatively rare, particularly as regards the workings of regulation.

The MTO-sea study is a practical application of a number of concepts from recent research into safety. The principal concept is “making safety”. Safety is seen as something a system does, rather than something it has, or is given. It is a “dynamic non-event”. In this concept, people make a positive contribution to safety by adapting to circumstances and filling the shortfalls in the system design. This view is in contrast to the conventional view of seeing operators as a source of human error, to be contained by ever-increasing formalisation introduced to address an earlier problem. Individuals and teams perform “integration work” [Lützhöft, 2004], adapting their workplace and their way of working to meet operational demands within the constraints provided – hand-written notices are perhaps the most obvious form of this.

At an organisational level, “making safety” requires that safety in an organisation is proactive rather than reactive, and that the organisation is resilient as well as reliable. A resilient organisation is able to cope with disturbances and changes before, during and after a problem occurs. Such organisations include employers, manufacturers, training academies, and regulators.

The paper discusses changes to the nature of work at the sharp end and how resilience is introduced, summarises the situation at the blunt end and then offers some concluding remarks.

2 THE SHARP END

2.1 Working at the Sharp End

The professional seafarer has always had to make the best use of the tools available to achieve commercial success without sacrificing the safety margin. At times, this balance cannot be upheld, as was seen in the grounding of the M/S Casino Express; a classical case of balancing production versus protection [SHK RS 2006:01, Reason, 1997]. The rapid introduction of computer systems for navigation is crudely indicated by the increase from 22 to 40 items of equipment specified at the main workstations between 1990 and now [ISO 1990, 2006]. The number of tools and their variants make it hard for mariners to keep up-to-date on their job function and its task requirements, academies cannot keep up, and learning on the job has inherent risks.

There have been incidents attributed to the mismatch between the seafarer and the technical systems. These are very similar to incidents in other sectors brought about by 'clumsy automation'. In some ways, bridge automation is repeating the pattern in aircraft cockpits.

2.2 Making Safety at the Sharp End

Relatively little is known about how operators cope with modern software-intensive systems and the accumulation of equipment to be found on many bridges. The crew can modify and adapt bridge equipment, they can find ways of coping with equipment that is undependable or difficult to use, and find ways of dealing with shortfalls in documentation, procedures etc.

The on-going MTO-sea study sets out to understand the challenges posed by modern bridge equipment and the ways in which the crew adapt to make best use of it. The study is a co-operation between Kalmar Maritime Academy, VTI (The Swedish National Road and Transportation Research Institute), Lloyds Register and C.N.S. Systems AB. The stakeholders in this endeavour are many and diverse; cadets – new officers, teachers and staff at maritime academies, personnel at shipping companies, regulators, manufacturers and researchers.

The study centres on data gathering by final year cadets from Kalmar Maritime Academy. The cadets are currently at sea, with aids to keeping a log of adaptations and an analysis of the bridge of their ship. The cadets were introduced to methods and techniques by which they may analyse their own work situation and collect information on a variety of ships' bridges, by studying the bridge of "their ship" during their apprentice period. They describe the bridge, take photos and perform discussions and evaluations

with the bridge officers. Each student will be individually debriefed on their return and when all are back, a series of lectures will be given. They will contain summary information on the results, including good and bad examples.

3 THE BLUNT END

Descriptions of the blunt end have reflected the formal organisation, either as nested systems [cf. Moray 1994] or as levels [Rasmussen 1997]. However, in practical operation, shipping is best considered as a system of systems. A simplified set of technical systems would include equipment design and supply, ship design and construction, and ship operation. Other systems would be concerned with e.g. crew supply and training. Each system has its own regulation.

Collectively, these control loops tend to encourage what has been described as ‘dis-integration’ [Courteney, 1996]. *“This is not meant to imply decay, but rather the opposite of integration: the control is organised in such a way as to work against its own stated objective of improving safety in the area of ‘human factors’”*.

Feedback loops and data gathering are vital for the dynamic control of risk. The organisation needs “requisite imagination” – the ability to anticipate when and how calamity might strike. It needs to be able to detect ‘weak signals’ – to have a good early warning system. The sharp end needs to adapt minute by minute, day by day, while the outer loops (the blunt end) operate on much longer time constants. This section examines the dynamics of the blunt end. A greatly simplified model of regulation of navigation is shown at Figure 1. Navigation equipment supply, which seems to be a self-generated technology push; ship design and construction, where major incidents (e.g. Erika, Prestige) stimulate regulation; operation of the ship and crew. Feedback from operation (the dotted line) appears to be mostly informal, via professional societies that have formal representation. These bodies are also important conduits for forward-looking research. Activities to provide resilience, ‘making safety’ are those around the dotted line, and are largely distinct from the main path of regulatory control input.

Figure 2 shows the regulatory cycle; whilst something of an over-simplification, the essentially isolated nature of individual regulatory changes is correct. The consequences of increasing the rate of regulation are shown at Figure 3.

Key to Figure 1: IACS: International Association of Classification Societies, IEC: International Electrotechnical Commission, IMarEST: Institute of Marine Engineering, Science and Technology, IMO: International Maritime Organisation, IMPA: International Maritime Pilots’ Association, ISM: International Safety Management System, NGO: Non-Governmental Organisation, NI: Nautical Institute P&I: Protection & Indemnity, PSC: Port State Control, RIN: Royal Institute of Navigation, RINA: Royal Institution of Naval Architects

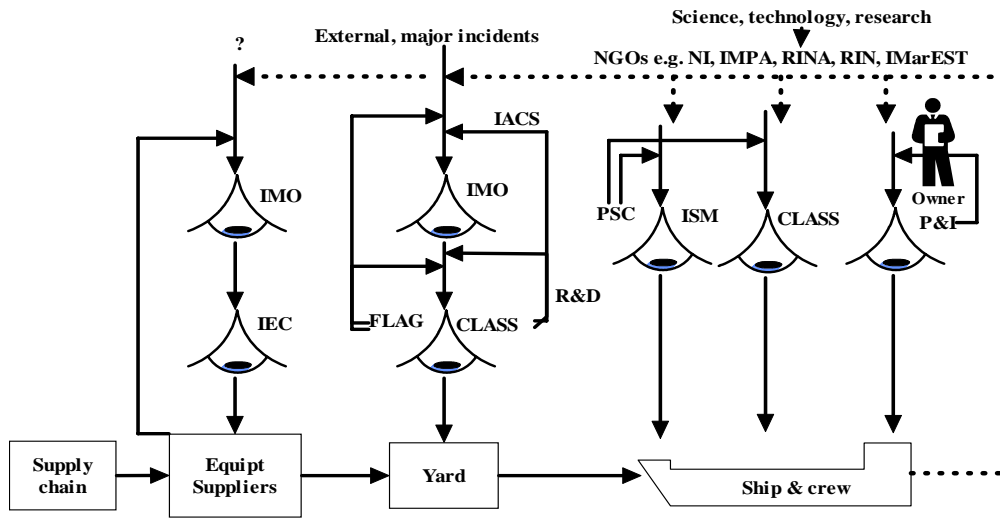


Fig. 1. Simplified model of regulation of bridge design and equipment. Key on previous page

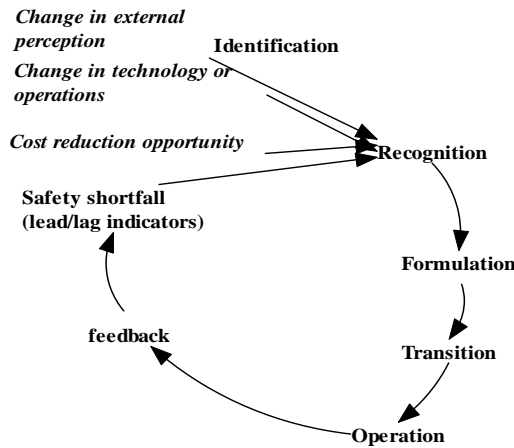


Fig. 2. The regulatory cycle. Input or feedback errors lead to inappropriate formulation. In general, regulations are seen as isolated control inputs, and systemic implications are not explicitly considered as part of the process

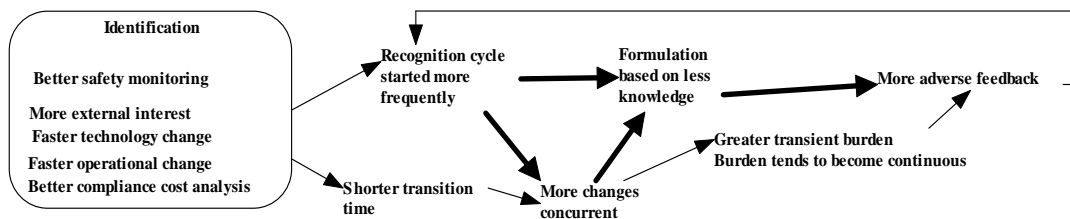


Fig. 3. The adverse effects of external conditions forcing a higher rate of new regulation.

3.1 Working at the Blunt End

The regulator and equipment manufacturing stakeholders have been busy pursuing a course of introducing new technology on the basis of improved safety. Approximately

60 new or updated Performance Standards for navigation equipment have been adopted over the last decade. The belief is that more and better electronics will improve safety. This is not without substance. However, each major item of new equipment has brought human-systems issues with it.

The requirements for the Global Maritime Distress and Safety System (GMDSS) were adopted in 1988 and implemented 1992-1999. Whilst increasing safety at sea, it also led to the loss of the Radio Officer, increased the watchkeeping load on the bridge team, and brought a great many false alarms. The Performance Standard for Automatic Identification System (AIS) was adopted in 1998, and implementation was completed by the end of 2004. Over this period, the user requirement changed from shore use to onboard operation, and then a new security role was added. The equipment has not changed the formal status of Collision Regulations, but has opened up new forms of behaviour in actual practice. Well-intentioned “technology push” has treated user and organisational issues as side-effects to be managed during operation.

3.2 Making Safety at the Blunt End

The regulatory understanding of, and response to, human-system issues arising from bridge technology has a much slower time constant than the control loops introducing such technology. The history is summarised in this section as ‘weak signals’, ‘wake up call’, ‘high level regulatory response’, and ‘equipment regulation’.

Weak signals (1990) on human-system issues were present among the general enthusiasm for new technology [NRC, 1990], based on [Schuffel, 1989]. *“Schuffel determined that a single-manned, advanced technology bridge was safer and more efficient (as measured by the trackkeeping and mental workload parameters) than either of the other two bridge configurations.”* However the risks of passive monitoring and single-person errors were highlighted. The NRC report recommended *“The introduction of new technology should consider ships as sociotechnical systems, consisting of personnel, technology, organizational structures, and an external environment. Change in any of these four subsystems should suggest appropriate changes in the others.”*

Wake up call (1995-1997) was provided by the Report on the 1995 grounding of the ROYAL MAJESTY [NTSB, 1997]: *“Thus, while human engineering is a known concept in the marine industry, there have not been any unifying efforts to integrate this concept into the marine engineering and manufacturing sector. Additionally, human engineering in the broader context of Human System Integration has been given little or no consideration. Consequently, the potential for error causing behavior related to these [automated] systems has not been adequately addressed by the marine industry”.*

High level regulation (1998-2001): A new comprehensive regulation to address some of the most fundamental human element concerns relating to the ship’s bridge was drafted as Regulation 15 in Chapter V (Navigation) of SOLAS [IMO, 2001]. This was a high level set of principles, quite unlike the detailed technical specifications that the industry was accustomed to.

Equipment regulation (2006+): Work on more specific standards and guidance to assist the implementation of Regulation V/15 was started.

3.3 Wider Hopes for the MTO Sea Project

In the short term, the study will help the Academy to keep its training and education of future officers up to date. Teachers at maritime academies will obtain the means to teach that safety is something that is made, not given. They will be able to give awareness of Bridge Resource Management, risk assessment and ISM skills. The cadets will receive a good basis for e.g., superintendent skills. The knowledge thus gathered will be integrated into the training of officers and made available for all interested operators and parties within the shipping industry.

A further long-term benefit for the academies is that this study hopes to build lifelong learning links, and they will receive operational feedback – like any academic department which sends students into the field to collect data (for example geology and sociology departments). The study will also provide useful feedback to the shipping companies involved in Swedish cadet training.

One main objective is to increase the interest of new officers in these questions, to start a lifelong learning process and to contribute to professional development. More importantly, students will be taught to identify the correct receiver of various types of information they have found, and to formulate their feedback in an appropriate manner in order to be interesting to the receiver. For instance, when talking to a technical supervisor in a shipping company, one would discuss efficiency and economical gains. When providing feedback to a manufacturer, context of use is expected to be valuable.

Thus, cadets will learn to provide professional responses to complex equipment, and furthermore this study will add interest to sea time as well as providing them with a NI certificate denoting them “Feedback officer”.

Manufacturers often want specific feedback on specific issues. We know from earlier studies that technology manufacturers agree on the importance of feedback from seafaring personnel on the use and context of use for their respective equipment. However, it is hard to get feedback from this group, and especially so from those sailing the high seas. This study will get feedback on user aspects of their equipment.

In the longer term, feedback on how the bridge team has to adapt around Type Approved, regulated bridge equipment and layouts will be of value to the regulators. With a better understanding of the context of use, standards and regulations can be drafted so that the equipment has to meet the needs of the seafarer, rather than the seafarer having to work around the needs of the equipment. At the moment, feedback to regulators is informal through professional bodies such as the Nautical Institute, and pilots and masters associations. Supplementing this with systematic data gathering from recent time at sea should assist in ‘honouring the seafarer’.

4 CONCLUDING REMARKS

The authors believe that the industry should do more than just teach operators not to make mistakes and be a source of ‘human error’. The requirement is to equip seafarers to be a central component in nested, resilient systems. The MTO-Sea study will help the Academy to keep its training and education of future officers up to date. Staff and teachers at maritime academies will get information on how to teach that safety is something that is made, not given. The study hopes to build lifelong learning links, enabling the Academy to receive operational feedback, and the professional development of the cadets to make contributions to the industry. As regards the blunt end, Figure 4 shows a more desirable arrangement of self-balancing systems.

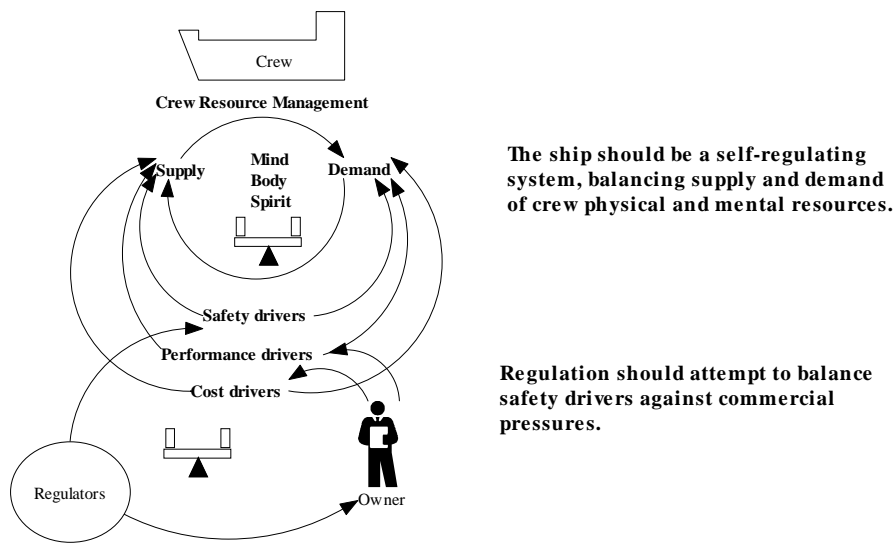


Fig. 4 A model of regulation that might help a ship to be self-regulating

Given the pace of change in commerce and technology, requisite imagination will require rapid dynamics. How can more rapid response and greater lead be achieved? The use of high-level principles and goals (rather than detailed prescription) is clearly desirable. The assessment of management processes, and the extent to which they are adaptive, would provide a lead indicator. Process assessment based on ISO/IEC 15504 [ISO/IEC 2004] provides the combination of rigour and flexibility, and a range of useful process standards exists.

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